Dynamic Distribution using (DER) Distributed Energy Resources

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I. INTRODUCTION

There are four realities facing future power systems that require rethinking the distribution system and the use distributed energy resources, DER. These realities require that the T&D system;

- Provide for load grow with enhanced stability with minimal growth of the transmission system.
- Make greater use of renewable such as wind and photovoltaic systems.
- Increase energy efficiency and reduce pollution and greenhouse gas emissions.
- Increase availability of high power quality for sensitive loads.

Currently there are DER applications that can help alleviate some of these issues, but a comprehensive solution require integrating DER with distribution in such a way as to radically changing the way distribution and transmission are used to deliver power to the customer. The basic concept is to use DER to move all load following requirements to the distribution system and allow for intentional islanding within the distribution system to enhance reliable and provide high power quality to customers with sensitive loads.

II. ISSUES/ REALITIES

Provide for load grow with enhanced stability with minimal growth of the transmission system.

It is well known that our transmission system is under greater stress every year resulting in a greater possibility for stability problems. The most basic solution to our overstress system is to build more transmission. It is also known that it is very difficult to construct new transmission lines. One way to handle load growth and enhance stability with transmission is to use the existing system in a more effective way. For example if a transmission line was loaded uniformly over a 24 hour period the total energy transmitted could more than double with increased stability margins. This could be pushed further by assuming that all generation and transmission could operate at a fix loading 24 hours, seven days a week. Of course this neglects the fact that loads and demands for electrical energy are always changing. DER on the distribution system can meet all load following needs. The objective is to place storage and generation throughout the distribution system of such ratings and at such locations that the transmission system could be uniformly loaded 24 hours a day. With correct sizing and placement of DER it should be possible to have a system with less losses, more transmission capabilities, more stable markets, higher level of security and double the total energy transfer over a 24 hour period without new generation or transmission.

Make greater use of renewable such as wind and photovoltaic systems.

Currently the low penetration levels of renewable systems cause few problems. As penetration becomes greater the available of wind and sun become a greater problem requiring central generation to provide the power backup. Such systems are intermittent sources and can cause similar stability problems found with intermittent loads such as roiling mills and arc furnaces. In any case there is a need for reserves when there is no sun or wind. The obvious solution for high penetration levels of renewable sources is also DER on the distribution system. Without storage and local generation there is a technical limit to the amount of wind generation that can be added to the greater electric supply system, perhaps as much as 20% of the peak demand. Because wind generation is intermittent, and because it may not occur when electricity is needed (i.e., during periods when demand for electricity is high), wind generation must be supplemented with "dispatchable" resources such as storage and local generation that fill-in when both demand for electricity is high and wind generation is low. One can now envision a system where there is DER and renewable sources at the same substation. The DER has a duel role; enhancing transmission system loading and provide a power fill-in when intermittent generation is low.

Increase energy efficiency and reduce pollution and greenhouse gas emissions

Use of waste heat through co-generation or combined heat and power (CHP) implies an integrated energy system, which delvers both electricity and useful heat from an energy source such as natural gas, [1]. Combined heat and power or CHP — which produces both electricity and useable heat using distributed generation — converts as much as 90 percent of it's fuel into usable energy. This intrinsic efficiency and resulting environment improvements has enormous potential benefits to the power system. Unlike electricity, heat, usually in the form of steam or hot water, cannot be easily or economically transported long distances, so CHP systems typically provide heat for local use. Electricity is more readily transported than heat, generation of heat close to the location of the heat load will usually make more sense than generation of heat close to the distribution substation. Under present conditions, the ideal positioning of cooling-heating-and-power cogeneration is often hindered by the distribution system and its operation, whether legitimate or obstructionist. In a new distribution system such obstacle would not exist. CHP plants can be sited optimally for heat utilization. A distribution system that is integrated with DER is very *pro-* CHP. A principle example of effective use of CHPs is the microgrid, which is designed to allow CHP systems to be placed anywhere the waste heat, can be effetely used, [2].

Sensitive loads

Many industrial, commercial and residential customers now require a high level of quality of power do to the increase of digital systems and sophisticated controls. These customers are especially sensitive to momentary voltages sags caused by remote faults. Power quality, availably and reliability are important issues to all customers. There have been proposals to create a self-healing power system with nine-nines of reliability to meet customers' demands. This approach is complex and costly and is not necessary if distribution and DER are well integrated. DER has the potential to increase system reliability and power quality due to the decentralization of supply. Increase in reliability levels can be obtained if DER is allowed to operate autonomously in transient conditions, namely when the distribution system operation is disturbed upstream in the grid. In addition black start functions can minimize down times and aid the re-energization procedure of the bulk distribution system. Distribution systems that are designed to island loads with generation can provide the necessary high levels of power quality, availably and reliability required by the customer. One example is the microgrid concept that clusters loads with generation and can intentionally island the DER with loads, [2].

III. BASIC CONCEPT

To realize the potential of integrating the distribution system with DER one must take a system approach which views generation, storage, protection and loads as an integral part of the distribution system. Such integration must not depend on fast, complex command and control systems. Each active component of the new distribution system must react to local information such a voltage, current and frequency to correctly change it's operating point. This is no different than what we currently do on our bulk power system. Currently generation and transmission does not use fast centralized communication for load following, response to transients or faults. Disturbances on a Dynamic Distribution Systems require that some of the generation, storage and corresponding loads need to separate from the distribution system to isolate sensitive loads from the disturbance (and thereby maintaining service) without harming the integrity of the remaining T&D system. The task is to achieve this functionality without communications and extensive custom engineering and still have high system reliability and DER placement flexibility. To achieve this we promote a peer-to-peer and plug-and-play model for each DER component including intermittent sources.

Local control without fast-centralized communication requires that each active component controls its reactive power injection based on local voltage and has a power vs. frequency droop function to insure power balance when the parts of the feeders intentionally island during a disturbance.

The peer-to-peer concept also insures that there are no components, such as a master controller, generation or central storage unit that is critical for operation of a distribution feeder. For example this implies that the system can continue operating with loss of any component or generator. With one additional source (N+1) we can insure complete functionality with the loss of any source. Plug-and-play implies that a unit can be placed at any point on the distribution system without re-engineering. Plug-and-play functionality is much akin to the flexibility one has when using a home appliance. That is it can be attached to the electrical system at the location where it is needed. In the new distribution system this implies that DER devices can be located on the distribution system where needed.

The basic *dynamic distribution architecture* is shown in Figure 1. This consists of a group of radial feeders. Each feeder at the substation has the same structure, which includes storage and distributed generation. Storage helps keep the power demand from the grid constant as the loads and renewable sources change their operating points over a day, week or season. The generator is used to assist the storage during high load times. The microgrid is included in this architecture to provide for increase energy efficient through the use of combined heat and power, (CHP) and high power quality for sensitive loads through intentional islanding. The local improvement in power quality is an important value added function. The full feeder could also provide higher power quality using the same static switch, SS, functionality, [3]. In this case storage and generation would make up for the power loss from the grid through their respective power vs. frequency droop functions

There are interesting DER sizing issues related to how we want the system to operate. For example if the storage is very large to allow for total load swings over a 24 hour period there is no need for distributed generation. I expect this will not be

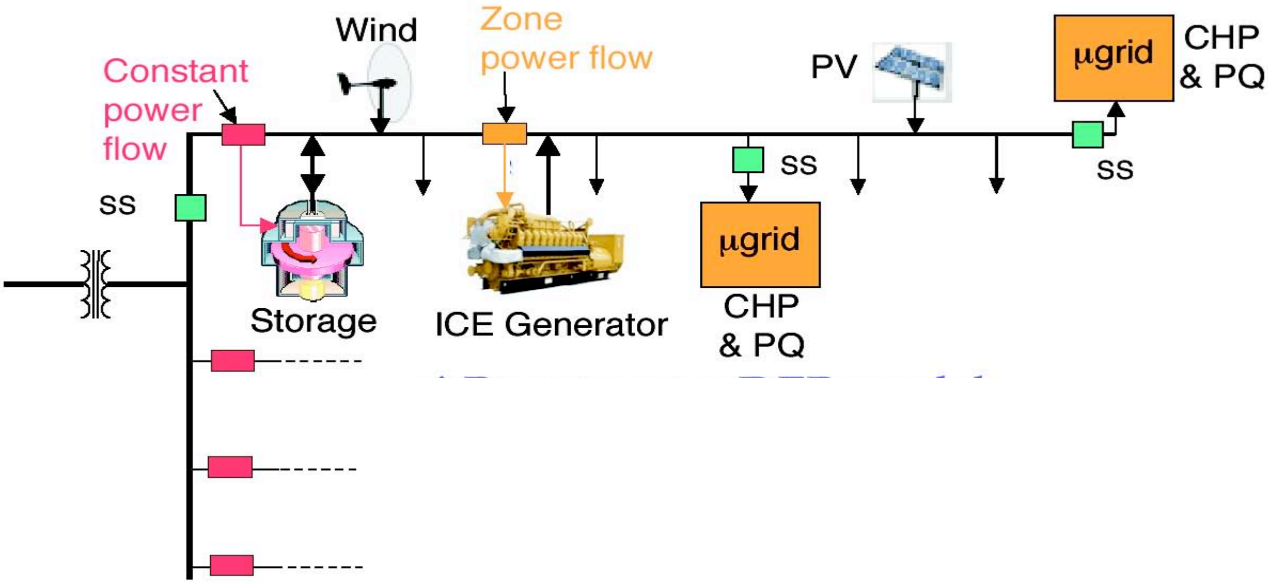

Figure 1. Dynamic Distribution Architecture

practical and the generator would be added to reduce the required storage capacity.

Storage insures constant power loading for the bulk power system. During low load periods the extra energy will be stored. The bulk power system, storage and local generation will meet peak loads. For example the "zone power flow allows for load changes down stream. For example if the "zone power flow" is set at ½ MW when the flow increases the generator will increase its output to hold the flow at ½ MW and reduces output if the flow drops below ½ MW. If the total load becomes less that ½ MW the generator output becomes zero and cannot absorbed the extra power. In this case the controls will reset them selves so that the "zone flow" will equal the load demand.

The "constant power flow" used with the storage is the same, as the "zone power flow", except it will absorb energy when the "constant power flow" set point is larger than the total load demand. This is what we would expect during low load time like the middle of the night.

IV. CONCLUSION

A comprehensive solution to the new distribution system require integrating DER with distribution in such a way as to radically changing the way distribution and transmission are used to deliver power to the customer. The basic concept is to use DER to move all load following requirements to the distribution system and allow for intentional islanding within the distribution system to enhance reliable and provide high power quality to customers with sensitive loads. With correct sizing and placement of DER it should be possible to have a T&D system with less losses, more transmission capabilities, more stable markets, higher level of security and double the total energy transfer over a 24 hour period without new generation or transmission

REFERENCES

[1] Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, "2001 BTS Core Databook," Office of Building Technology, July 13, 2001

[2] Lasseter, R., *and Paolo Piagi, "MicroGrids: A Coceptual Solution,"* PESC'o4 Aachen, Germany 20-25 June 2004

[3] Zang, H., M.Chandorkar, G. Venkataramanan, *"Development of Static Switchgear for Utility Interconnection in a Microgrid."* Power and Energy Systems PES, Feb. 24-26, 2003, Palm Springs, CA.

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